REMARKS

I. INTRODUCTION

In response to the Office Action dated July 18, 2003, claim 36 has been cancelled. Claims 1, 2, 4-9, 11-17, 35, and 37-39 remain in the application. Re-consideration of the application as amended is respectfully requested.

II. NON ART REJECTIONS

In paragraphs (1)-(2) of the Office Action, claim 36 is rejected under 35 U.S.C. §112, first paragraph, as failing to comply with the written description requirement.

In response, in order to expedite prosecution and without prejudice to pursuing the cancelled claim or similar claims in a continuation application, Applicants' attorney has cancelled claim 36.

In paragraph (3) of the Office Action, claim 38 is rejected under 35 U.S.C. §112, first paragraph, as failing to comply with the written description requirement. In paragraph (4) of the Office Action, claim 39 is rejected under 35 U.S.C. §112, first paragraph, as failing to comply with the written description requirement. In both cases, the Office Action asserts that the instant specification does not provide support for graded GaN layers.

In response, Applicants respectfully disagree. The specification does provide support for a graded gallium nitride (GaN) layer. For example, paragraph [0012] teaches:

> A typical semiconductor film comprises a substrate and a graded gallium nitride layer deposited on the substrate having a varying composition of a substantially continuous grade from an initial composition to a final composition formed from a supply of at least one precursor in a growth chamber without any interruption in the supply.

Moreover, the instant specification teaches such graded GaN layers as they relate to stresses within the GaN layers. For example, paragraphs [0025] and [0026] teach the following.

> [0025] The principal feature of the present invention is that the composition is varied continuously between the initial composition 106 and the final composition 108 without any interruption in precursor 110 supply. From ongoing materials studies it appears that the lack of interruption in the growth process prevents the layers with low aluminum content from dissipating the elastic energy associated with the lattice mismatch between material A and material B. Thus a larger amount of

> compressive strain is present in the layer structure than is found when using other methods. In many cases the compressive stress is large enough to counterbalance the tensile stress induced by the cool-down procedure such that the net stress in the epitaxial layers is compressive. Compressively-strained films do not crack, hence preserving the properties of any device that may have been subsequently deposited and processed.
> [0026] The grade 114 can be accomplished by a variety of methods known to those skilled in the art, such as...

Particularly with respect to claim 38, the specification further teaches that the graded GaN layer and stresses in the graded layer relate to the elimination of cracking in the graded GaN layer. See paragraph [0013], "the GaN films grown using the method of the present invention are under compressive stress, which eliminates the tendency of GaN to crack. The deposition sequence consists of a continuous grade...". Further with respect to claim 39, the specification teaches at paragraph [0008] "GaN films exhibit cracking when the tensile stress exceeds approximately 400 MPa." Accordingly, Applicants respectfully submit the subject matter of claims 38 and 39 are described in the specification in such a way as to reasonably convey to one skilled in the art that the inventor, at the time the application was filed, had possession of the claimed invention as required under §112, first paragraph. Withdrawal of these §112 rejections is respectfully solicited.

III. PRIOR ART REJECTIONS

In paragraphs (5)-(6) of the Office Action, claims 1, 2, 4-9, and 11-39 were rejected under 35 U.S.C. §103(a) as being unpatentable over Edmond et al., U.S. Patent No. 5,739,554 (Edmond) or Redwing et al., U.S. Patent No. 5,874,747 (Redwing) in view of Goetz et al., U.S. Patent No. 6,441,393 (Goetz).

Applicants respectfully traverse these rejections for the reasons set out below.

Independent claim 1 is directed to a semiconductor film, comprising a silicon substrate and a graded gallium nitride layer deposited on the silicon substrate having a varying composition of a substantially continuous grade from an initial composition to a final composition. The cited references do not teach nor suggest these various elements of Applicants' independent claim. Particularly, the teachings of the cited references, alone or in combination, do not teach or suggest a graded gallium nitride layer deposited on a silicon substrate.

The Office Action essentially asserts that both Edmond and Redwing teach various graded GaN layers that read on the graded gallium nitride layer of the present independent claim. The Office Action acknowledges that neither Edmond nor Redwing teach a silicon substrate, disclosing instead use of a silicon carbide substrate. However, the Office Action asserts that Goetz teaches, among other things, a substrate of sapphire, silicon carbide, silicon or gallium arsenide or gallium nitride and depositing a buffer layer 12 thereon. The Office Action then asserts that it would have been obvious to a person of ordinary skill in the art at the time of the invention to modify Edmond or Redwing with Goetz's substrate of silicon because substitution of known equivalents for the same purpose is held to be obvious.

Applicants respectfully disagree.

Applicants submit that silicon carbide and silicon are not equivalents in the context of the present invention as asserted in the Office Action. Furthermore, the teachings of each of the cited references, alone and in combination, would not direct a skilled artisan to employ a graded GaN layer on a silicon substrate as presently claimed.

Although the manufacturing challenges are similar, it is significantly more difficult to grow gallium nitride on silicon than on silicon carbide because both the thermal expansion and lattice mismatch differences between gallium nitride and silicon are significantly greater than those between gallium nitride and silicon carbide. See, for example, paragraph [0008] of the specification as filed, duplicated here.

> [0008] The growth of GaN on silicon substrates presents similar challenges as on sapphire and silicon carbide. The lattice mismatch between the (001) plane of GaN and the (111) plane of silicon is 17.6%, compared to 16% for sapphire and 3.5% for silicon carbide. The use of a thin AlN buffer has yielded GaN films on Si(111) with as low as 3×10^9 threading dislocations per square centimeter. However, the thermal expansion mismatch of GaN with silicon is +31%, compared to –26% for sapphire and +17% for silicon carbide. (The positive sign indicates a thermal expansion coefficient larger for GaN than for the substrate.) Assuming for the sake of demonstration that the GaN film is stress-free at the growth temperature (typically 1000 degrees centigrade), a positive thermal expansion mismatch would result in a GaN film under tensile stress after cool-down to room temperature. GaN films exhibit cracking when the tensile stress exceeds approximately 400 MPa. Cracks generally render devices inoperable due to electrical shorts or open circuits. In general the stress associated with the lattice mismatch, including any relaxation effect that may occur during growth, is referred to as "grown-in stress". The stress arising from the thermal expansion mismatch when the film is cooled from the growth

temperature to room temperature is referred to as "thermal stress". The sum of the grown-in stress and thermal stress is the net stress in the film.

None of the cited references can be read to teach or suggest a graded GaN layer on a silicon substrate in view of these difficulties. Furthermore, because of these property differences, there would be no reasonable expectation of success when growing gallium nitride on silicon in view of teachings in Edmond and Redwing. Moreover, Applicants note that even though silicon substrates were well known at the time of the Edmond and Redwing patent filings, neither patent suggests that silicon substrates may be used. Even Goetz, which mentions use of a silicon substrate, explicitly teaches an intervening low temperature buffer layer 12 as acknowledged by the Office Action. Finally, Applicants submit that the cited references, individually and when combined, teach away from the claimed invention as discussed hereafter.

Edmond describes a double heterostructure for a light emitting diode comprising a layer of aluminum gallium nitride having a first conductivity type; a layer of aluminum gallium nitride having the opposite conductivity type; and an active layer of gallium nitride between the aluminum gallium nitride layers, in which the gallium nitride layer is co-doped with both a Group II acceptor and a Group IV donor, with one of the dopants being present in an amount sufficient to give the gallium nitride layer a net conductivity type, so that the active layer forms a p-n junction with the adjacent layer of aluminum gallium nitride having the opposite conductivity type. Regarding substrates, Edmond discusses the benefits of SiC over sapphire, noting that crystal lattice match and thermal stability (among other properties between the substrate and Group III nitrides) are generally useful in producing a light emitting diode. See col. 3, lies 2-26. Thus, Edmond can not be read to suggest a graded GaN on a silicon substrate, a combination that has a greater lattice and thermal expansion mismatch as noted above. Edmonds teaching of such properties teaches away from a combination of GaN on silicon as presently claimed.

Redwing describes a green-blue to ultraviolet light emitting semiconductor laser having a top contact, a Bragg reflector, cladding layer, active layer, cladding layer, buffer, substrate, bottom contact and a passivation layer. The key aspect is a Ga*N material on a base structure comprising a SiC substrate selected from a group consisting of 2H-SiC, 4H-SiC and a-axis oriented 6H-SiC. Furthermore, the cladding layers have larger band gaps than the active layer and are complimentarily doped. Throughout the specification, Redwing repeatedly stresses the desirability and importance of

employing a SiC substrate. See e.g., col. 4, lines 10-51. However, Redwing also notes that differences in lattice constants and thermal expansion coefficients cause cracking in GaN layers grown on SiC substrates (an undesirable result). See col. 4, lines 52-61. As with Edmond above, such teaching by Redwing teaches away from GaN on a silicon substrate. Further, Redwing notes that a buffer layer grown on the substrate improves the quality of GaN grown on substrates such as Si. See col. 4, lines 52-65.

Finally, Goetz describes a semiconductor device having n-type device layers of III-V nitride having donor dopants such as germanium (Ge), silicon (Si), tin (Sn), and/or oxygen (O) and/or p-type device layers of III-V nitride having acceptor dopants such as magnesium (Mg), beryllium (Be), zinc (Zn), and/or cadmium (Cd), either simultaneously or in a doping superlattice, to engineer strain, improve conductivity, and provide longer wavelength light emission. Importantly, Goetz specifically teaches a low temperature buffer layer 12 disposed between the substrate and a gallium nitride layer 13. See FIG. 1 and col. 6, lines 8-14. Such teaching directs a skilled artisan away from a graded gallium nitride layer on a silicon substrate as claimed.

In response to Applicants' prior arguments regarding the buffer layer of Goetz, in paragraph (8) the Office Action has asserted that Goetz's teaching that the "various layers" may be smoothly graded over a finite thickness "would include grading the composition of the buffer layer." See col. 3, line 20 to col. 4, line 5. Applicants respectfully disagree.

Goetz only indicates broadly what composition the "various layers" <u>may</u> comprise as they are discussed further in the specification. The examples and the details of the specification are necessary to determine which technique and composition form is possible for a particular layer. Throughout the specification, Goetz teaches low temperature buffer layers 12, 22, 52, indicating repeatedly that such a layer is used "due to difficulties in nucleation of the single crystalline III-V nitride layers on foreign substrates". In each case, Goetz notes only that a material such as GaN <u>or</u> AlN is used. See col. 3, lines 30-35, col. 4, lines 8-13 and lines 50-54. Nowhere does Goetz teach or suggest any of the buffer layers 12, 22, 52 as having a graded composition or define an example composition of a such a hypothetical graded buffer layer. Applicants submit that Goetz can not be read to have such teaching applied to the buffer layers if not one example of such a graded buffer layer on a substrate is taught by Goetz.

In addition, Applicants respectfully submit that even when combined, Edmond or Redwing and Goetz would teach away from Applicants' invention. Edmond and/or Redwing would direct a graded GaN layer on a SiC substrate as discussed above. Although the additional teachings of Goetz may suggest a silicon substrate is possible, this would contradict the emphasis of a SiC substrate directed by Edmond and emphasized by Redwing. In addition, nothing in Goetz would suggest that a silicon substrate could be used without a buffer layer between the substrate and the GaN layer as Goetz teaches. Moreover, the teaching of Redwing would also direct the inclusion of a buffer layer with a silicon substrate as noted above. Accordingly, Applicants submit that the combined teachings of Edmond, Redwing and Goetz would teach away from a graded GaN layer on a silicon substrate as presently claimed.

Because neither Edmond, Redwing nor Goetz, alone or in combination, teach or suggest a graded gallium nitride layer on a silicon substrate as presently claimed, Applicants submit that the present §103 rejection is overcome.

Moreover, the various elements of Applicants' claimed invention together provide operational advantages over Edmond, Redwing, and Goetz. For example, the use of silicon substrates rather than sapphire or silicon carbide substrates in the production of semiconductor will result in additional cost savings. See paragraph [0007] of the application as filed.

Thus, Applicants submit that independent claim 1 is allowable over Edmond, Redwing, and Goetz. Further, dependent claims 2, 4-9, 11-17, 35, and 37-39 are submitted to be allowable over Edmond, Redwing and Goetz in the same manner, because they are dependent on claim 1 and thus contain all the limitations of the independent claim. In addition, dependent claims 2, 4-9, 11-17, 35, and 37-39 recite additional novel elements not shown by Edmond, Redwing, and Goetz.

IV. CONCLUSION

In view of the above, it is submitted that this application is now in good order for allowance and such allowance is respectfully solicited. Should the Examiner believe minor matters still remain that can be resolved in a telephone interview, the Examiner is urged to call Applicants' undersigned attorney.

Respectfully submitted,

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